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Agricultural technology for sustainable development

Report of the Secretary-General

Summary

A broad portfolio of policies, approaches and inputs is necessary to achieve the Sustainable Development Goals, in particular to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. The application of science and technology in developing sustainable agricultural practices can play an important role in providing solutions to achieve the Sustainable Development Goals. Such solutions will support smallholder and family farmers in their efforts to sustainably increase productivity and incomes, contribute to the creation of sustainable food production systems, and synergize the achievement of other goals and targets in a holistic and transformative way.

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I. Introduction

1. The present report has been prepared in response to General Assembly resolution 70/198, in which the Assembly requested the Secretary-General to submit, at its seventy-second session, a report on the implementation of that resolution.

2. In its resolution 70/1, the Assembly emphasised the need for more holistic development and attention to interlinkages among the 17 Sustainable Development Goals and 169 targets, noting that the challenges and commitments identified were interrelated and called for integrated solutions and that to address them effectively a new approach was needed. The transformative vision of the 2030 Agenda and the Sustainable Development Goals is rooted in previous calls by policymakers and practitioners to break down the silos that have hampered development efforts in the past.

3. The present report presents a review of key challenges pertaining to sustainable agricultural development, provides examples of trends in sustainable agricultural technologies that tackle a broader set of issues than those reflected under Sustainable Development Goal 2 and makes recommendations for the way forward.

II. Overview

4. Agriculture is at the heart of the Sustainable Development Goals and key to achieving them. Sustainable Development Goal 2 indirectly impacts all other Goals, emphasizing the need to pay attention across all the Goals to promote synergies while minimizing negative feedbacks. Agricultural technologies can address a host of sustainable development challenges and are recognised as having an important role in the successful implementation of the goals and targets of the 2030 Agenda for Sustainable Development (see General Assembly resolution 70/198).

5. Farmers are by far the largest source of investment in agriculture in low-income and middle-income countries.[1] Small family farms are central to rural growth and contribute to Sustainable Development Goal 2, as well as other Goals. However, long-standing barriers, such as inadequate access to natural resources, inputs, technology, finance, markets and other resources and services hinder their participation in food systems and value chains. As a result, small family farms which account for 80 per cent of the food produced in Asia and sub-Saharan Africa continue to be, paradoxically, among the poorest, most vulnerable and most food-insecure people in the world. Technological, social, economic and institutional innovations that build on the knowledge and capacities and respond to the needs and realities of family farmers, small-scale producers and rural indigenous populations can help them surpass some of these barriers, sustainably improve livelihoods and overcome the vicious cycle of poverty, vulnerability, food and nutrition insecurity and natural resource-based degradation that they usually face.[2] Agricultural technologies — encompassing crops, livestock, fisheries, aquaculture and forestry — have improved the productivity of agriculture and enhanced the sustainability and resilience of food

[1] Food and Agriculture Organization of the United Nations (FAO), *The State of Food Agriculture: Innovation in Family Farming* (Rome, 2014).

[2] International Fund for Agricultural Development (IFAD), *Rural Development Report 2016: Fostering Inclusive Rural Transformation* (Rome, 2016).

production systems at the local level.[3] If widely adopted, such technologies can play a critical role in securing global food supplies over the long term.

6. Sustainability requires ensuring that appropriate agricultural technologies are embedded into entire value chains based on a food systems perspective rather than isolated aspects of production. This approach allows us to address the immediate barriers facing small-scale farmers and consider linkages arising from growing pressure on natural resources. Furthermore, it allows us to monitor and benefit from synergies across all the Sustainable Development Goals.[4]

7. What is needed are policy changes, multi-stakeholder engagement and increased responsible investments in agriculture and food systems covering all aspects of the food production system: research and development in agricultural technologies, adaptation of existing technologies to local contexts and support for dissemination and adoption efforts. We need to move beyond a singular and linear approach of research-extension-farmers to embrace the entire agricultural innovation system and address complex agricultural problems in order to achieve increases in productivity and measure the sustainability of an intervention by its holistic impact. This requires embracing complexity and factoring in multidimensional outcomes as we move along the system from production to consumption.[5]

8. It is through holistic approaches that development efforts can accelerate a crucial transformation from household to institutional levels.

III. Challenges

9. Among the major trends that have profound implications for policymakers and practitioners in terms of agriculture are changing farm demographics, the pressure to simultaneously raise agricultural productivity and rebuild the resource base and the increasing vulnerability of food systems. These trends call for renewed emphasis on the role of agricultural technologies, not only to achieve Sustainable Development Goal 2 but also to overcome a host of development challenges linked to the attainment and visions of the 2030 Agenda.

A. Changing farm demographics

10. Demographic forces are changing the structure of farmlands, with contrasting trends. On the one hand, the percentage of people living in rural areas across the world is declining.[6] The absolute number of rural dwellers across much of East Asia, South-East Asia and Latin America is falling and in the Middle East and North Africa it is growing ever more slowly. On the other hand, in sub-Saharan Africa and countries such as India, rural populations are still increasing despite high levels of urbanization, with consequences for the average size of farms. Data from 167 countries provides compelling evidence of decreasing farm size in most low-

[3] Mark W. Rosegrant and others, *Food Security in a World of Natural Resource Scarcity: The Role of Agricultural Technologies* (Washington, D.C., International Food Policy Research Institute, 2014).

[4] Birgit Kopainsky, Theresa Tribaldos and Samuel T. Ledermann, "A food systems perspective for food and nutrition security beyond the post-2015 development agenda", *Systems Research and Behavioral Science* (April 2017).

[5] Tools such as the iSDG are supporting these efforts in several developing countries.

[6] United Nations, *World Urbanization Prospects: The 2014 Revision*, ST/ESA/SER.A/366 (New York, 2014).

income and middle-income countries.[7] At the same time, Africa is becoming increasingly urban; without improving access to education, health care, transportation, the Internet and stronger livelihoods in rural areas, over 50 per cent of the African population is projected to live in cities by 2050.

11. Increased migration by male jobseekers is accelerating the feminization of farming in many low-income countries.[8] As women often face additional barriers to participating in markets and value chains, such as unequal access to land, credit and education, the result is that female-headed households in rural areas are increasingly disadvantaged yet less able to rise out of poverty.[9]

12. Rural populations are also confronted with the prospect of rising dependency ratios. This demographic trend is especially prominent in Africa, home to the youngest population in the world. Young people account for 60 per cent of all unemployment on the continent, resulting in increased migration to urban areas in search of job opportunities.[10] Overall, trends in urbanization compounded by lack of productive assets for young people suggest that rural populations are ageing faster than their urban counterparts.

13. Policies and cultural norms related to land ownership and intergenerational transfer are often counterproductive to improving and promoting the engagement of women and youth in agriculture.[11] Female farmers lack equal rights to own land in more than 90 countries.

14. Urbanization will also profoundly affect land use. Global urbanization trends will result in the loss of millions of hectares of farmland by 2030, mostly in Asia and Africa.[12]

B. Increasing agricultural productivity and enhancing the resource base

15. Since the 1970s, growth rates in annual crop yields have slowed considerably. According to the Food and Agriculture Organization of the United Nations (FAO), annual yield growth hovers between 1 and 2 per cent for most of the world's major food crops. Continued existence of major variations in productivity across regions, including persistently large potential yield gaps in sub-Saharan Africa, signal a need for novel approaches to sustainably increase production. As of 2017, existing high-input, resource-intensive farming systems, which have caused massive deforestation, water scarcities, soil depletion and high levels of greenhouse gas emissions, cannot deliver sustainable food and agricultural production. Innovative systems are needed that protect and enhance the natural resource base while increasing productivity.[13] It is critical to identify and promote sustainable agricultural technologies that can close the productivity gap, enhance the resource base and address interlinkages.

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[7] Sarah K. Lowder, Jakob Skoet and Terri Raney, "The number, size, and distribution of farms, smallholder farms, and family farms worldwide", *World Development*, vol. 87 (November 2016).

[8] FAO, *The Future of Food and Agriculture: Trends and Challenges* (Rome, 2017).

[9] If migrants are able to find successful job opportunities, resultant remittances have the potential to reduce the gendered-productivity gaps, hence empowering female-led farming households, as well as opening up new economic and leadership opportunities for women and youth at the community level (FAO, *The Future of Food and Agriculture*).

[10] IFAD, *Rural Development Report 2016*.

[11] Deon Filmer and Louise Fox, *Youth Employment in Sub-Saharan Africa* (Washington, D.C., World Bank, 2014).

[12] Christopher Bren d'Amour and others, "Future urban land expansion and implications for global croplands", *Proceedings of the National Academy of Sciences of the United States of America* (November 2016).

[13] FAO, *The Future of Food and Agriculture*.

16. In Asia and Latin America, where the "green revolution" has resulted in widespread adoption of high input-intensive agriculture, a shift towards sustainable agricultural production that enhances the natural resource base is needed. In sub-Saharan Africa, the green revolution has not yet taken place. The region has the opportunity to sustainably increase agricultural production and productivity by using improved technologies and building on integrated approaches. Agroecology, for example, can result in sustained agricultural intensification while enhancing livelihoods and resilience, adapting to climate change and contributing to its mitigation, and preventing the degradation of natural resources.[14]

17. Securing access to diverse and locally adapted crop varieties and livestock breeds through quality genetic material is an important vehicle for improving smallholder productivity, climate resilience and nutrition.

18. Despite significant investment in improving the functioning of formal seed systems, the adoption of improved seed varieties developed by public and private research institutions remains unsatisfactory across much of the developing world. The limited commercial viability of reaching farmers in remote areas who may buy only small amounts of seeds, along with restrictive, costly or ineffective regulatory environments, are among the obstacles to enhancing seed security.[15]

19. Informal seed systems still play a critical role in securing access to seeds.[16] This has led to a rise in State-supported initiatives to promote access at the community level, mainly through locally managed seed banks. Such initiatives safeguard indigenous knowledge and promote the proliferation of diverse genetic resources. Yet ensuring such structures have adequate technical and managerial capacity to ensure farmers' rights to the seeds they develop is a challenge, as is enacting appropriate national legislation to protect farmers' rights, as enshrined in article 9 of the International Treaty on Plant Genetic Resources for Food and Agriculture.

20. The FAO Quality Declared Seed System that was created in 2006 provides a semi-formal type of seed system for the participation of smallholder farmers in the multiplication of improved open pollinated seeds. Vehicles like this have a strong potential to bridge the gap between seed shortages and delivery of improved seed varieties.

21. Considering the challenge of climate change and need for local adaptation, these informal or semi-formal seed systems will need to play a major role in improving resilience and diversifying food production.[17]

C. Increasing vulnerability of food systems

22. Climate change is creating ever more frequent disruptions in agriculture.[18] Low-income and middle-income countries in tropical areas that host the largest number of farmers are especially vulnerable and expected to experience

[14] (Hans P. Binswanger-Mkhize and Sara Savastano, "Agriculture intensification: the status in six African countries", *Food Policy*, vol. 67 (February 2017)).

[15] Indeed, recent efforts by the Government of Tanzania to protect farmers from unscrupulous seed dealers illustrates the challenge many developing countries face: ensuring access to quality seed without penalizing informal or farmer-managed systems.

[16] Shawn McGuire and Louise Sperling, "Seed systems smallholder farmers use", *Food Security*, vol. 8, No. 1 (February 2016).

[17] Emile A. Frison, "From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems" (International Panel of Experts on Sustainable Food Systems, 2016).

[18] FAO, *The Future of Food and Agriculture*.

disproportionate declines in productivity.[19] Given the importance of agricultural production for rural growth, under a high-impact climate change scenario poverty is expected to increase by up to 122 million people by 2030.[20] This scenario also points to the likelihood of a fundamental shift in geographical food production patterns, ostensibly increasing reliance on a smaller number of producing countries concentrated in high-potential regions.

23. Invasive pests and emerging diseases are an additional threat to food systems. Crop pests and pathogens are expanding their range as a result of global trade, migration and climate change. Their estimated annual cost of US$ 70 billion is expected to increase unless investments are made in surveillance, prevention, containment and awareness.[21]

24. There is increasing recognition that the traditional foods of indigenous communities can make a strong contribution to addressing hidden hunger or undernutrition. However, the increased migration of youth to urban areas threatens the long-term viability of indigenous food systems and, as reported by FAO, knowledge about thousands of edible and medicinal plants built up over centuries of trial and error could be lost forever, along with the diverse ecosystems that host them.[22]

IV. Trends

25. Investments in research and development for agricultural technologies are widely recognised as a contributor to development (see General Assembly resolution 70/198). At the same time, the geographical distribution of spending on food and agricultural research and development is changing and middle-income countries are now investing more in agricultural research and development than high-income countries.[23] Globally, total private sector investment is comparable to what is invested by the public sector.

26. However, the difference in expenditure ratios between middle-to-high-income countries and low-income countries is widening. Most African countries still fall short of the minimum investment target set by the African Union and the United Nations,[24] while extension systems remain weak and fragmented, with limited technical, functional, institutional and organizational capacities. Reform towards pluralistic, demand-driven and market-oriented extension is needed to provide rural communities with a wide range of skills and knowledge and to facilitate broader interactions among different stakeholders to help them access support and services required for improving their livelihoods.[25]

27. In this context of growing yet uneven financing for agricultural research and development, the following seven trends in agricultural technologies for

[19] FAO, *2016 The State of Food and Agriculture: Climate Change, Agriculture and Food Security* (Rome, 2016).

[20] Stephanie Hallegatte and others, *Shock Waves: Managing the Impacts of Climate Change on Poverty* (Washington, D.C., World Bank, 2016).

[21] Corey Bradshaw and others, "Massive yet grossly underestimated global costs of invasive insects", *Nature Communications*, vol. 7, No. 12986 (October 2016).

[22] FAO, *The Future of Food and Agriculture*.

[23] Philip G. Pardey and others, "Agricultural R&D is on the move", *Nature*, vol. 537, No. 7620 (September 2016).

[24] Agricultural Science and Technology Indicators, CGIAR, 2016.

[25] FAO, *Tailoring Rural Advisory Services for Family Farms*, policy paper (Rome, FAO and Global Forum for Rural Advisory Services, 2016). Available from www.fao.org/3/a-i5704e.pdf.

development have been identified and are described in detail in paragraphs 30 to 62 below:

(a) Rapid evolution in science and technology innovations;

(b) Biological innovations;

(c) Holistic agricultural development;

(d) Urban food production;

(e) Water-saving and irrigation technology;

(f) Post-harvest and food systems;

(g) Institutional support and information and communications technology (ICT) innovations.

28. Agricultural technologies should holistically address agricultural productivity, post-harvest losses and nutritional security across the food system. They should be affordable, durable and sustainable and easily used and disseminated (see General Assembly resolution 70/198, para.13) and inclusive of women and youth. Taking climate change into account, they should also support adaptation by drawing on farm or livelihood diversification, while remaining mindful of weak social protection, existing gender inequalities and migration.[26]

29. The suite of technologies available to farmers to promote sustainable food production should be as broad as possible, from agroecology to agricultural biotechnologies.[27]

A. Rapid evolution in science and technology innovation

30. New agricultural innovations have rapidly changed technologies and the availability of novel methods and processes. For example, the application of the next generation of genome sequencing linked with high throughput phenotyping and molecular marker-assisted breeding technologies will enable much faster development of new crop varieties that are resistant to intractable biotic stress problems, such as drought, salinity and rust diseases. The development and open access of megadata and information that is analysed, accessed and exchanged through cloud computing, social media, broadband Internet and mobile networks, even in remote areas, will bring profound changes for agricultural research, extension and rural development. Increasing labour scarcity in some developing countries is leading to the rapid mechanization of farming.

B. Biological innovations

31. The potential for biological methods to improve soil quality and reduce damage caused by pests is promising. One study analysed the use and performance of insect biological control agents for the control of insect pests across 148 countries.[28] Analysis of three decades of data revealed that although the number

[26] FAO, "Urbanization, rural transformation and implications for food security: online consultation on the background document to the CFS Forum", 15 March-6 April 2016.

[27] See, for example, FAO, "Concept note: FAO symposium on the role of agricultural biotechnologies in sustainable food systems and nutrition, February 2016. Available from www.fao.org/3/a-ax916e.pdf, and FAO, "Key messages for agricultural biotechnologies symposium", 2016, available from www.fao.org/3/a-bc613e.pdf.

[28] Matthew J.W. Cock and others, "Trends in the classical biological control of insect pests by insects: an update of the BIOCAT database", *BioControl*, vol. 61, No. 4 (August 2016).

of methods being introduced for testing is falling, a higher proportion of them are successful. In addition, the number of countries implementing biological control methods has markedly increased. The cassava mealybug biological control programme, executed in the 1980s and early 1990s across 24 African countries, introduced an environmentally, economically and socially beneficial approach that had a cost/benefit ratio of 1:242, discounted over 20 years. The use of alternative methods to control pests ranges from integrated pest management to holistic approaches of agroecology.

32. Biofertilizers are gaining importance for use in crop production and restoring the soil's natural fertility. Much of the recent growth in this area stems from the development of effective policy and regulatory frameworks in the developed countries and selected Asian countries that have enhanced the availability and consistency of high-quality products. In sub-Saharan Africa, the adoption of these technologies has proven more challenging. One of the biggest hurdles is the absence of supportive policy and regulatory frameworks, but more investment is also needed for localized research to improve awareness and promote the involvement of the private sector.

33. Growing of legumes before wheat is an example of a viable avenue to add up to 300 kilograms of nitrogen per hectare into the soil. Similarly, integrating leguminous shrubs and trees in Southern Africa has added up to 250 kilograms of nitrogen per hectare into the soil, outcompeting synthetic fertilizer applications while increasing resilience.[29]

34. Integrated cropping systems, such as the widely recognized "push-pull" farming system in East Africa,[30] are successful not only for achieving biological pest control through companion plants but also for significantly improving soil fertility by reducing weed pressure through a permanent soil cover of nitrogen-fixing leguminous crops. The fodder crop *Brachiaria*, used in the push-pull system as a trap crop, is known to restore soil structure and reduce pasture degradation in Brazil.[31] Such a system fits the latest developments in regenerative agriculture, with the aim of restoring and building soil fertility through the use of perennial crops while contributing to climate change adaptation and mitigation.[32]

35. Agricultural biotechnologies,[33] ranging from simple applications, such as artificial insemination and tissue culture, through marker-aided selection to genetic engineering and novel genome editing methods, have demonstrated potential to increase agricultural productivity in environmentally friendly ways.[34,35]

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[29] FAO, "Urbanization, rural transformation and implications for food security".

[30] An ongoing initiative is currently underway to expand the "push-pull" system outside East Africa.

[31] FAO, "Urbanization, rural transformation and implications for food security".

[32] See also the 4 per 1000 initiative; available at http://4p1000.org/.

[33] Based on the definition of "biotechnology" in article 2 of the Convention on Biological Diversity, as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use", FAO considers the term "agricultural biotechnologies" to encompass a broad range of technologies used in food and agriculture for a number of different purposes, such as the genetic improvement of plant varieties and animal populations to increase their yields or efficiency; the characterization and conservation of genetic resources for food and agriculture; plant or animal disease diagnosis; and vaccine development.

[34] United Kingdom of Great Britain and Northern Ireland, Government Office for Science, "The future of food and farming: challenges and choices for global sustainability — final project report", Foresight project (London, 2011).

[35] John Ruane, James D. Dargie and Catriona Daly, eds., *Proceedings of the FAO International Symposium on the Role of Agricultural Biotechnologies in Sustainable Food Systems and Nutrition* (Rome, FAO, 2016).

36. Recent developments in advanced genome editing have seen the emergence of a new set of technologies, such as Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR), that make more precise changes to the genetic makeup of a living organism. Such gene-editing technology offers a wide range of new opportunities to accelerate genetic improvement cycles. The science and technology of genome editing is advancing rapidly and is the subject of research in many laboratories, including in developing countries. Such new technology is relatively inexpensive and its rapid expansion should be expected, while at the same time it opens new challenges in terms of regulation, policies and intellectual property rights.

37. The decision to use any agricultural biotechnology must be taken by individual countries and should be informed by a careful evaluation of the benefits and potential risks. The International Symposium on Agricultural Biotechnologies[36] organized by FAO in February 2016[37] is an example of a neutral forum for the exchange of ideas and practices involving States, intergovernmental organizations, research institutions, farmer organizations, academia, civil society and the private sector. The consensus has been reached that biotechnologies and agroecological applications are complementary ways to sustainably address food insecurity and malnutrition. Agricultural biotechnologies can be used in production systems, based on agroecological principles, to enhance productivity while ensuring sustainability, conservation of genetic resources and use of indigenous knowledge.

38. To extend the dialogue on agricultural biotechnologies to the regional level, consultation meetings have been planned by FAO for Asia and the Pacific (Malaysia, 11-13 September 2017), Africa (November 2017), Latin America and the Caribbean (2018) and the Near East (2018). The main goals of these consultations are to identify: (a) elements of a comprehensive regional action plan and road map, including capacity development initiatives, (b) priority themes and partners for South-South cooperation mechanisms and (c) regional research and development themes that address constraints for improved food security and nutrition.

C. Holistic agricultural development

39. In paragraph 14 of its resolution 70/198, the General Assembly called for the augmentation of sustainable agriculture and management practices, such as conservation agriculture.

40. Conservation agriculture builds on the principles of no-tillage, permanent soil cover by residues or cover crops and crop rotation, which can have beneficial impacts at the level of Sustainable Development Goals 13 and 15.[38] Based on the positive impacts observed by rotation, intercropping and relay cropping of legumes with maize, the adoption of good agronomic practices of crop rotation and residue retention should form the basis of subsequent adoption of no-till methods.[39]

41. Regarding soil fertility, data from a 20-year trial by the International Institute of Tropical Agriculture shows that the combination of organic inputs with fertilizer resulted in maize yields of 2.8 tons per hectare, compared to 1.7 tons per hectare when only synthetic fertilizer was used. Such integrated soil fertility management

[36] See www.fao.org/about/meetings/agribiotechs-symposium/en/.

[37] With funding support from Agriculture and Agri-Food Canada, the Ministry of Economic Affairs of the Netherlands, and the United States Department of Agriculture, Foreign Agricultural Service.

[38] See, for example, Kazakhstan case study, in FAO, "Urbanization, rural transformation and implications for food security".

[39] FAO, "Urbanization, rural transformation and implications for food security".

practices can not only benefit total yields (Sustainable Development Goal 2) and their stability but also improve the soil carbon content (Sustainable Development Goal 13), highlighting its potential for mitigating carbon emissions.[40]

42. In the Indo-Gangetic plains, resource-conserving technologies have increased wheat yields, accompanied with cost savings of 20 per cent. In Asia, farmers have also shifted during the dry season from growing rice to maize-legume intercropping, doubling their profits (Sustainable Development Goal 1) while reducing their synthetic fertilizer usage (Sustainable Development Goal 15) and increasing their yields (Sustainable Development Goal 2).[41] In the Sahel region, Building Resilience and Adaptation to Climate Extremes and Dangers (BRACED) projects are building on centuries of local innovations through approaches that combine the physical (improved techniques for soils and agricultural productivity), economic (savings and credit support) and social (community radio with climate focus) dimensions of agriculture.

43. The concept of climate-smart agriculture brings these multidimensional benefits up to scale. In an Indian case study, the adoption of different agricultural technologies, including crop insurance or weather-based crop agro-advisories, was largely context-dependent, influenced by such factors as amounts and variability of rainfall and cash liquidity.[42] Focusing on soil health, a "slash-and-mulch" system[43] in Central America has replaced traditional shifting cultivation, doubling yields (Sustainable Development Goal 2) while building soil nutrient stock (Sustainable Development Goal 15) and allowing for diversification in production (Sustainable Development Goal 1).

44. The importance of the local context is accentuated by the impact of climate-smart agriculture varying across space and time; decisions at the household level will have aggregated effects from the plot to the community and regional levels and are amplified by the diversity of stakeholders involved.[44] FAO identified the undoing of environmentally harmful subsidies and support measures as one common area for strengthening climate mitigation and adaptation; however, even with widespread adoption of climate-smart agriculture, FAO noted that this may fall short of what is needed to meet global climate targets because large adjustments are required in food systems at large.[45] One pathway for such a transformation of agriculture, in line with agroecological principles and embedded within the food system, has been articulated in the International Assessment of Agricultural Knowledge, Science and Technology for Development report for 2009.

45. Currently, the trend is to expand from a climate-smart model to a more holistic approach, such as agroecology, which has a track record of adapting novel technologies with local know-how and solutions.[46] Agroecology takes a food system approach in applying ecological concepts and principles to optimize interactions between plants, animals, humans and the environment. Building synergies,

[40] Dries Roobroeck and others, "Integrated soil fertility management : contributions of framework and practices to climate-smart agriculture", Practice Brief, climate smart agriculture (July 2016).

[41] FAO, "Urbanization, rural transformation and implications for food security".

[42] Arun Khatri-Chhetri and others, "Farmers' prioritization of climate-smart agriculture (CSA) technologies", *Agricultural Systems*, vol. 151 (February 2017).

[43] FAO, "Urbanization, rural transformation and implications for food security".

[44] An Notenbaert and others, "Targeting, out-scaling and prioritizing climate-smart interventions in agricultural systems: lessons from applying a generic framework to the livestock sector in sub-Saharan Africa", *Agricultural Systems*, vol. 151 (February 2017).

[45] FAO, "Urbanization, rural transformation and implications for food security".

[46] Altieri et al., 2015, 2017; de Molina et al., 2017; Pimbert, 2015.

agroecology can support food production while restoring the ecosystem services and biodiversity.[47]

46. Following the International Symposium on Agroecology for Food Security and Nutrition (Italy, 2014),[48] FAO organized regional meetings on agroecology in Latin America and the Caribbean (Brazil, 2015), sub-Saharan Africa (Senegal, 2015); Asia and Pacific (Thailand, 2015) and Europe and Central Asia (Hungary, 2016), as well as a national meeting in China in 2016, co-organized with the Chinese Academy of Agricultural Sciences.

47. The New European Consensus on Development: Our World, Our Dignity, Our Future[49] commits to support agroecological practices and actions to reduce post-harvest losses and food waste, as well as to protect soils, conserve water resources, halt, prevent and reverse deforestation, and maintain biodiversity and healthy ecosystems.

D. Urban food production

48. Given the positive transformative potential of strengthened urban-rural linkages in achieving sustainable development and the need to take action to fight hunger and malnutrition among the urban poor, as acknowledged in General Assembly resolution 70/198, as well as the advances made during the United Nations Conference on Housing and Sustainable Urban Development (Habitat III), approaches to strengthening urban and peri-urban agricultural production will contribute to achieving the Sustainable Development Goals.

49. Urban agriculture has a long history of improving food and income security of urban dwellers. A recent assessment finds that globally, 11 per cent of irrigated cropland and almost 5 per cent of all rain-fed cropland is urban.[50] If urban boundaries are extended by 20 kilometres, these figures jump to 60 per cent and 35 per cent, respectively. Solid data on growth in urban agriculture is lacking, but these numbers, combined with evidence from a large number of national studies across cities in Asia and Africa, suggest that urban and peri-urban agriculture is on the rise. Such cities as Kampala, Kumasi and Phnom Penh are approaching higher degrees of self-sufficiency for some food products.[51]

50. However, urban agriculture may pose environmental and sanitary problems, for example when poor urban dwellers living in high-density areas keep livestock, affecting human health through possible disease transmission and adding to the problem of waste management.

E. Water-saving and irrigation technology

51. In paragraph 10 of its resolution 70/198, the General Assembly underlined the importance of the sustainable use and management of water resources to increase

[47] FAO, Agroecology Knowledge Hub database, available from www.fao.org/agroecology/overview/en/ (accessed 16 July 2017).

[48] With support from France, the Swiss Development Cooperation and the Foreign Office of Agriculture of Switzerland.

[49] See Official Journal of the European Union, vol. 60, 30 June 2017. Available from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2017:210:FULL&from=EN.

[50] Thebo, A L, P Drechsel, and E F Lambin. 2014. "Global Assessment of Urban and Peri-Urban Agriculture: Irrigated and Rainfed Croplands." *Environmental Research Letters* 9 (11): 114002.

[51] Francesco Orsini and others, "Urban agriculture in the developing world: a review", *Agronomy for Sustainable Development*, vol. 33, No. 4 (October 2013).

and ensure agricultural productivity, and called for further efforts to develop and strengthen irrigation facilities and water-saving technology.

52. At the household level, access to credit will be critical in order for farmers to invest in micro-drip or solar-powered irrigation equipment. In Nepal, for example, multiple user water irrigation and micro-drip irrigation have a cost/benefit ratio of 1:18 and 1:30, respectively.[52] At the landscape level, the Productive Safety Net Programme (PSNP) in Ethiopia not only facilitated the rehabilitation of more than 167,000 hectares of land (Sustainable Development Goal 15) but benefited local irrigation projects, which successfully increased agricultural productivity. When combined with complementary interventions, including a household asset-building programme (Sustainable Development Goal 1), Ethiopian households were found to be more food-secure (Sustainable Development Goal 2), using credit for productive purposes and investing in improved agricultural technologies.[53]

53. Water-saving technologies can also contribute to climate mitigation (Sustainable Development Goal 13), without compromising productivity (Sustainable Development Goal 2). For example, the Alternate Wetting Drying method in rice production[54] has been tested extensively in South-East Asia. It reduces water use by 15 to 25 per cent and methane emissions by 30 to 70 per cent. Similarly, the System of Rice Intensification has doubled yields while reducing irrigation needs and cutting methane emissions. The combination of rice farming with aquaculture in Asia showcases the potential for technology to not only increase income by 400 per cent compared to a rice monoculture (Sustainable Development Goal 1) but also improve family diets (Sustainable Development Goal 2) since a paddy field of 1 hectare can yield as much as 9 tons of rice and 750 kilograms of fish a year.[55]

F. Post-harvest and food systems

54. One avenue for delivering holistic impacts recognised by the General Assembly is to increase the use of agricultural technologies that support more sustainable food systems and have a positive impact on the entire value chain, including technology for post-harvest crop storage, processing, handling and transportation, including in pressing environmental circumstances (see resolution 70/198, para. 14).

55. A food systems perspective has the potential to address multiple Sustainable Development Goals,[56] highlighting the importance of addressing interventions at the level of food systems activities, such as via addressing post-harvest losses as opposed to solely focusing on agricultural production. The United Nations Zero

[52] IDE and others, "Anukalan: driving small farmer investment in climate-smart technologies", available from www.weadapt.org/sites/weadapt.org/files/anukulan-overview.pdf.

[53] FAO, "Urbanization, rural transformation and implications for food security".

[54] Arnold van Huis and others, *Edible Insects: Future Prospects for Food and Feed Security*, FAO Forestry Paper, vol. 171 (Rome, FAO, 2013).

[55] FAO, "Urbanization, rural transformation and implications for food security".

[56] Food system outcomes (SDG 2) include food availability (target 2.1), food utilization (target 2.2), social welfare and food access (target 2.3) and environmental capital (targets 2.4 and 2.5). Food system activities, such as producing, processing and consumption address targets 2.3 and 2.4. These are connected with the drivers of global environmental change (Sustainable Development Goals 14 and 15), including changes in land cover, water availability, biodiversity, and socioeconomic drivers (Sustainable Development Goal 5), including demographic, economic or sociopolitical changes. Additional interactions between these two drivers, such as climate change (Sustainable Development Goal 13), subsequently influences food system activities and outcomes.

Hunger Challenge is one of several initiatives aiming to achieve transformation by breaking down silos using a food systems perspective.

56. As proposed by the International Food Policy Research Institute for achieving target 12.3 of the Sustainable Development Goals, developed countries should focus on reducing food waste, whereas developing countries should focus on reducing food loss in the short term and leapfrogging best practices for reducing food waste at a later stage. Post-harvest losses, while low in developed countries, are estimated to range between 10 and 40 per cent for some crops, reaching as high as 50 to 70 per cent in Africa.[57]

57. Recommended and proven technologies to address physical losses include the Purdue Improved Crop Storage Bag, as well as plastic and metal silos. Two large international actors are promoting their adoption: the International Maize and Wheat Improvement Center and the Feed the Future programme of the United States Agency for International Development. The benefits of their adoption extend beyond spoilage because farmers are able to delay their harvest sales and earn higher prices.[58]

58. Food systems are increasingly marked by concentration, which may reduce incentives for innovation. At the level of input provisions, three companies currently control 50 per cent of the seed market and five companies share 68 per cent of the agrochemical market. At the level of trade, power has become increasingly concentrated in large-scale retailers, with up to 90 per cent of the global grain trade controlled by just four companies.[59]

59. This concentration raises the question of the role of the public sector, especially to deliver innovations in agricultural food chains.[60] Beyond the need for public research and development and addressing credit constraints by adopters, increased investments are needed in physical infrastructure, particularly for rural roads. Such infrastructure investments, which reduce transaction costs, are also catalysts for increasing the incentives at the farmer level for the adoption of improved agricultural production technologies.[61]

G. Institutional and ICT innovations

60. In paragraphs 7 and 11 of its resolution 70/198, the General Assembly encouraged the growth of agricultural cooperatives through easy access to affordable finance and the development of partnerships to support financial and market services, including training, capacity-building, infrastructure and extension services.

61. Efforts to improve social protection in the context of inclusive rural growth can offer a pathway out of poverty while reducing the overall vulnerability of food systems. Given the link between poverty and agricultural productivity, providing social protection and pursuing agricultural development in an integrated way offers synergies that can increase the effectiveness of both.

62. Trends in extension services have developed around the rise of novel information communication technologies in agriculture that are being successfully deployed in developing countries to overcome barriers to access information and

[57] Alliance for a Green Revolution in Africa, "Africa agriculture status report 2016: progress towards agricultural transformation in Africa", 2016.
[58] Ibid.
[59] Emile A. Frison, "From uniformity to diversity".
[60] A/RES/70/198.
[61] Jayne et al. 2016.

knowledge. In Uganda, for example, the Grameen Foundation's Community Knowledge Worker programme building on an SMS-based application successfully raised prices of participating farmers by 22 per cent and increased their knowledge by 17 per cent.[62]

V. Policy solutions

63. Member States are currently aligning their national policy environments with the 2030 Agenda. A holistic, integrated and systemic approach to policymaking is required, and is equally as important as the need to create incentives for environmentally sound and innovative technologies. It will be essential to develop informed and inclusive policies within the framework of the Sustainable Development Goals that take into account both synergies and trade-offs across the three sustainable development dimensions, as well as across all the Goals.

64. To address the challenges for agriculture and food systems, policymakers must embrace new processes to:

(a) Develop and implement transformational strategies and policies while understanding their systemic implications;

(b) Facilitate an enabling political environment for stakeholders to use technologies that are innovative, integrative and inclusive.

65. In order to ensure that no one is left behind, it is clear that strategies and measures must be developed in an integrated manner that is inclusive of the most vulnerable, particularly for agriculture and food systems.[63]

A. Beyond agricultural production

66. A transformative process towards holistic approaches, such as agroecology and agroforestry approaches that build on indigenous and traditional knowledge, is urgently needed.[64] A fundamentally different model of agriculture is required for more holistic strategies to build long-term fertility, healthy agroecosystems and secure livelihoods.[65]

67. The agriculture sector is inextricably linked with the entire food system. Policymakers are becoming more aware of the need to identify entry points for agricultural technologies that add value throughout the food system to improve the sustainability of storage, transport, trade, processing, transformation, retail, waste reduction and recycling, as well as the interactions among these processes. From a systemic perspective, policies that foster more localized and internalized food systems are essential in order to make more efficient use of resources in food cycles while maintaining standards of income and food production.[66]

68. Interventions to address the impacts of climate change, food losses and waste and sustainable rural-urban linkages, in combination with innovative food and agriculture technologies, can exploit synergies among different policy areas and support the systemic transition towards sustainable food systems.

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[62] FAO, *The State of Food Agriculture*.

[63] Lawrence Haddad and others, "A new global research agenda for food", *Nature*, vol. 540, No. 7631 (November 2016).

[64] FAO, *The Future of Food and Agriculture*.

[65] Emile A. Frison, "From uniformity to diversity".

[66] Ibid.

B. Climate change

69. Such practices as agroecology or organic and regenerative agriculture can buffer climate impacts through the diversification of crops, improving soil conditions, water retention and closed resource cycles (e.g., carbon cycles), thereby also contributing to mitigation of greenhouse gas emissions.[67] In addition, diversified and integrated agricultural technologies, such as weather forecasting and insurances that are available and affordable to farmers, have proven to be effective.[68]

70. The Paris Agreement on climate change provides the framework for all countries to set new political standards to hedge against climate impacts and mitigate emissions. Governments will need a systematic approach when developing new agricultural policies, requiring close collaboration among transdisciplinary teams sectorial ministries. In additional, national and mitigation plans require policy coherence: they can only be effective if they are part of broader, transformative policies on agriculture, rural development, food security and nutrition.[69]

C. Food losses and waste

71. Efforts to overcome managerial and technical limitations in harvesting techniques, storage and transportation systems can go a long way towards preventing food losses and waste, and more is needed to address the lack of standardized metrics and food waste data for decision makers.[70] In this context, the Food Loss and Waste Accounting and Reporting Standard enables companies, countries, cities and others to quantify and report on food loss and waste so they can develop targeted reduction strategies and realize the benefits of tackling this inefficiency.[71]

72. Progress is also being achieved through the FAO Save Food Initiative and the community of practice on food loss reduction, which promote good practices in this area, such as new food-drying technologies.

D. Rural-urban linkages

73. Fostering rural-urban linkages plays an increasingly important role in creating sustainable food systems since poorly integrated value chains are missed opportunities for market integration and diversification of activities by young producers and entrepreneurs in rural areas. Improved infrastructure in — and connectivity between — small and mid-size urban centres can bridge gaps in standards of living, facilitate access to markets and reduce food losses. A special session on rural-urban linkages at Habitat III concluded that these linkages also strengthen the inclusivity of agricultural value chains.

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[67] Altieri et al., 2015.

[68] Committee on World Food Security, High-Level Panel of Experts on Food Security and Nutrition, "Food security and climate change: a report by the High-Level Panel of Experts on Food Security and Nutrition", (Rome, 2012).

[69] FAO, *2016 The State of Food and Agriculture*.

[70] Committee on World Food Security, High-Level Panel of Experts on Food Security and Nutrition, "Food losses and waste in the context of sustainable food systems: a report by the High-Level Panel of Experts on Food Security and Nutrition" (Rome, 2014).

[71] See http://flwprotocol.org.

E. Actions and initiatives

74. Many Governments have adopted procedures to face these systemic challenges already: the publication *Better Policies for Sustainable Development* issued by the Organisation for Economic and Social Development in 2016 provides an overview of the importance of policy coherence and the different steps countries have undertaken to implement the 2030 Agenda.

75. Efforts are also under way to create an enabling environment at all levels for sustainable development in the spirit of global partnership and solidarity (see General Assembly resolution 70/198). A broad range of flagship initiatives, frameworks and platforms are being developed that implicitly or explicitly aim to foster the use of synergies among interlinked systems, such as the Global Land Tool Network (International Fund for Agricultural Development), the Food for the Cities Programme (FAO) and the sustainable food systems programme within the United Nations Environment Programme's 10-year framework of programmes on sustainable consumption and production patterns.[72]

76. The Changing Course in Global Agriculture Program works with pilot countries in sub-Saharan Africa to foster inclusive, integrated policy-planning processes, with a focus on sustainable food systems, rural poverty reduction and natural resource management.[73] Agroecological food production practices are being promoted thorough the FAO Agroecology Knowledge Hub, while innovative true-cost accounting approaches to internalize externalities are showcased by the Economics of Ecosystems and Biodiversity for Agriculture and Food initiative. Furthermore, the Beacons of Hope initiative undertakes a comprehensive review of good practices for sustainable food systems transitions. Also along these lines, the Technology Facilitation Mechanism was established under the 2030 Agenda for the mapping of existing technology facilitation initiatives, including support for policy formulation and the strengthening of technological capabilities and innovation systems.[74]

77. Other proactive initiatives in this context include the Agriculture Transformation Pathways Initiative and the Food, Agriculture, Biodiversity, Land-use, Energy initiative to develop long-term global and national pathways towards sustainable land use and food systems. Also, various United Nations platforms, such as the Committee on World Food Security, address the interlinkages among the Sustainable Development Goals and promote their added value for food security and food systems.

78. Sustained support from international agencies, Governments, the private sector and civil society is needed to improve data and information systems, scale up good practices and spin off dynamic initiatives to gain further momentum. With further support, all these efforts and good practices have the potential to facilitate the transformation needed within the food system to achieve a broad range of the Sustainable Development Goals.

VI. Conclusions and recommendations

79. The international community has recognized the necessity for integrated, transformative policymaking by adopting the 2030 Agenda, the Addis Ababa Action Agenda and the 2015 Paris Agreement on climate change. The level of

[72] See www.unep.org/10yfp/programmes/sustainable-food-systems-programme.

[73] See the programme online, available from http://changingcourse-agriculture.com/.

[74] See https://sustainabledevelopment.un.org/tfm.

transformation, integration and universality required from now on can be achieved only by adopting a holistic approach that delivers impacts across the full range of activities of the food system. On the basis of the analysis provided above, a first set of priority actions are recommended below.

A. Redirection of investment

80. "Business-as-usual" investment patterns will leave 650 million people (8 per cent of the global population) undernourished in 2030.[75] Additional investments of US$ 267 billion a year are needed, of which US$ 181 billion would go to rural areas, US$ 105 billion to stimulate pro-poor growth through agriculture and the remaining US$ 75 billion to social protection programmes.

81. Investments in agriculture should be directed not only to productivity-enhancing technologies but also to relevant food system activities, such as integrated agricultural production, reduced food losses and waste, sustainable processing and retail, access to services and markets, and provision of adequate information for food system stakeholders.

82. Channelling public and private investments from domestic and foreign sources to support small family farms is a powerful stimulus for rural growth. Such farms account for 80 per cent of the food produced in Asia and sub-Saharan Africa and yet remain among the poorest, most vulnerable and food-insecure groups. The Principles for Responsible Investment in Agriculture and Food Systems and the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries, and Forests in the Context of National Food Security adopted by the Committee on Food Security are key guidelines for investors in this context.

83. More investment is also needed for agricultural cooperatives by providing them with easy access to affordable finance, rural infrastructure and irrigation, strengthened marketing mechanisms, access to appropriate risk-management instruments and support for the participation of women and youth in economic activities.

B. Impactful, localized research and development

84. Promising examples from Asia and Europe demonstrate locally appropriate, cost-effective solutions that deliver across the multidimensional targets of Sustainable Development Goals 1-6 and 13-15. Community-managed seed banks, alternative protein sources for feed, integrated cropping systems, water-saving and irrigation techniques, integrated pest management and a continued attention to maintaining diversified habitats constitute practices that have proven their value in terms of yield, ecological and social sustainability. Research and development needs to be redirected to disseminating these practices further. Currently, the share of global public investment that supports research and development on agroecology, for example, is estimated at less than 1 per cent.

85. To achieve the Sustainable Development Goals and effectively adapt to context-specific climatic changes, investments in research and development, education and extension are required to empower and better serve the needs and demands of family farms in the context of local food systems. Building on the real-world problems of local communities and including their traditional knowledge in

[75] FAO, IFAD and World Food Programme, *Achieving Zero Hunger: The Critical Role of Investments in Social Protection and Agriculture*, 2nd ed. (Rome, FAO, 2015).

the establishment of innovative solutions will increase the sustainability of interventions.

86. Conducting research jointly with effective, pluralistic and demand-driven extension and rural advisory services is critical to ensure that agricultural technologies respond to the demands and needs of family farmers and smallholder producers. Locally adapted, modern machinery is equally important. While ICT holds potential to attract the younger generation, in many instances we lack the data to confirm its impact. Meanwhile, traditional means, such as radio (including community radio) and printed media, still go a long way.

C. Enabling frameworks

1. National and subnational levels

87. National and subnational governments remain the key players in the implementation of sustainable agriculture and food systems, in line with the 2030 Agenda and the Paris Agreement. They prioritize their objectives and investments in accordance with local needs and contexts. The necessary transformative and integrative reforms depend on the willingness of governments to review their institutional set-ups and overcome sectoral silos. Addressing the factors that impede transitions to diversified agroecological systems must become a higher priority.[76] Authorities depend on adequate, evidence-based tools to support integrative policymaking, and rely on transparent, inclusive decision-making processes that include all stakeholders, specifically the most vulnerable.[77]

88. The creation of incentives for the provision of ecosystem services is a powerful means by which authorities can support the scaling-up of innovative practices described in the present report. Authorities and private actors need to match such incentives with the necessary training of farmers and the other relevant stakeholders in the food system.

89. Other innovative approaches that incentivize producers and consumers can become powerful tools for achieving the 2030 Agenda. In this regard, initiatives that explore the internationalization of externalities in agricultural commodities deserve further research and political support.

90. Vertically integrated food systems provide standardized food for urban areas as well as formal employment opportunities. However, dependence on increasingly concentrated markets and chokepoints along the food supply chain need to be mitigated. The ecological footprint and the social and economic impacts of these lengthening chains need to be addressed and, where necessary, contained. On the other hand, well-organized and properly governed localized food systems have great potential to overcome the current challenges of food systems: they can significantly contribute to mitigating climate change and supporting adaptation, maintaining biodiversity and providing safe, adequate, accessible food and nutrition, including through urban and peri-urban agriculture (Sustainable Development Goals 8, 10 and 11). Stakeholders need to work together to gather data on informal, localized food systems, as recommended by the Committee on Food Security,[78] and to

[76] Emile A. Frison, "From uniformity to diversity".

[77] Paper by the multi-stakeholder Committee in Switzerland providing advice to the national government on issues of agriculture and food systems, see Swiss National FAO Committee, "Working towards Sustainable Agriculture and Food Systems", discussion paper, September 2016.

[78] Committee on World Food Security, "Policy recommendations: connecting smallholders to markets", available from www.fao.org/3/a-bq853e.pdf.

establish policies that support such systems in coherence with the flexibility provided in World Trade Organization (WTO) and other multilateral and bilateral trade agreements.

91. The current momentum around rural-urban linkages is relevant in this context, with potential for addressing rural-urban inequalities, access to markets and inclusivity of value chains from a systemic, spatial and territorial perspective. Such an approach can adequately support the trend of urban and peri-urban agricultural production, which is relevant for ecosystem services, and can help reduce urban poverty by addressing food security with a localized perspective.

2. Global level

92. Achievement of the Sustainable Development Goals also depends on an efficient and effective follow-up and review system in which countries, intergovernmental platforms, United Nations agencies and all stakeholders — including civil society, the private sector and academia — can share lessons and receive timely and adequate feedback and support regarding their progress. The high-level political forum on sustainable development, which organizes the follow-up and review of sustainable development commitments, should mobilize intergovernmental panels and platforms, such as the Committee on Food Security, to support the process of policy coherence, review and lesson-sharing on the Sustainable Development Goals related to agriculture and food systems.

93. Synergies, co-benefits and trade-offs among the Sustainable Development Goals need to be investigated and made apparent in the guidance to Governments provided by United Nations Conventions, intergovernmental platforms and United Nations agencies. Joint task forces should provide expert input and guidance to achieve policy coherence, coordination and integration across the Sustainable Development Goals.

94. Finally, the level of transformation and policy integration required among agricultural policies, environmental policies, social policies and economic policies can be achieved only if the relevant intergovernmental bodies, such as the African Union and the European Union, as well as the Group of 20 and similar entities:

(a) Recognize their ability to support members in the integration of policy frameworks;

(b) Support members in the institutional changes needed to break the silo approach. For example, taking the 2030 Agenda seriously can help to change the narrative around international trade (leaving no one behind) by integrating social and ecological targets with domestic Group of 20 growth and investment strategies. The Group of 20 can further support its members and WTO by addressing concrete synergies and trade-offs between possibly conflicting objectives, such as between a rule-based, open, non-discriminatory and equitable multilateral trading system and bilateral and regional investment and trade agreements, taking into account the critical social and environmental targets related to agriculture, food security and nutrition. The Group of 20 Action Plan on the 2030 Agenda for Sustainable Development and the Group of 20 Compact with Africa Initiative consequently need to be enacted with a systemic, integrated perspective on agriculture and food systems as a single priority.